Journal of Hospital Infection 102 (2019) 70–74

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Effects of a disinfection device on colonization of sink drains and patients during a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit

E. de Jonge [a,*], M.G.J. de Boer [b], E.H.R. van Essen [a], H.C.M. Dogterom-Ballering [c], K.E. Veldkamp [c]

[a] *Department of Intensive Care, Leiden University Medical Centre, Leiden, the Netherlands*
[b] *Department of Infectious Diseases, Leiden University Medical Centre, Leiden, the Netherlands*
[c] *Department of Medical Microbiology, Leiden University Medical Centre, Leiden, the Netherlands*

ARTICLE INFO

Article history:
Received 29 November 2018
Accepted 3 January 2019
Available online 9 January 2019

Keywords:
Pseudomonas aeruginosa
Colonization
Sinks
Intensive care unit
Resistance

SUMMARY

Background: Sink drains in intensive care units (ICUs) are frequently colonized with bacteria such as *Pseudomonas aeruginosa*.
Aim: To study the influence of installing disinfecting devices on sink drains on colonization of sinks and patients in an ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa*.
Methods: From 2010, there was a clonal outbreak of multidrug-resistant *P. aeruginosa* (MDR-PA). In April 2013, in ICU subunit A, the siphons draining these sinks were replaced by devices applying heat and electromechanical vibration to disinfect the draining fluid. In the other units, siphons were replaced by new polyvinyl chloride plastic siphons (control). In February 2016 the disinfecting devices were also placed at ICU subunit B.
Findings: Baseline colonization rate of sinks was 51% in ICU A and 46% in ICU B. In ICU A colonization decreased to 5% ($P < 0.001$) after the intervention whereas it was 62% in ICU B (control). After installing the disinfection devices in ICU B, colonization rate was 8.0 and 2.4% in ICU A and B, respectively (both $P < 0.001$ compared with baseline). Colonization in ICU patients decreased from 8.3 to 0 per 1000 admitted patients ($P < 0.001$) and from 2.7 to 0.5 per 1000 admitted patients ($P = 0.1$) in ICU A and B respectively.
Conclusion: Colonization with MDR-PA in sink drains in an ICU was effectively managed by installing disinfection devices to the siphons of sinks. Colonization of patients was also significantly reduced, suggesting that sink drains can be a source of clinical outbreaks with *P. aeruginosa* and that disinfecting devices may help to interrupt these outbreaks.

* Corresponding author. Address: Department of Intensive Care, Leiden University Medical Centre, B4-62, Albinusdreef 2, 2333 ZA Leiden, the Netherlands. Tel.: +31 (0)71 5265018; fax: +31 (0)71 5266966.
E-mail address: e.dejonge@lumc.nl (E. de Jonge).

https://doi.org/10.1016/j.jhin.2019.01.003

Introduction

Hospital outbreaks with nosocomial micro-organisms are a challenging problem in an era of increasing antibiotic resistance of micro-organisms, especially in intensive care units (ICUs), where there is an increasing tendency towards infections with Gram-negative bacteria. Although it has been reported that *P. aeruginosa* may also persist on dry surfaces for weeks to months, in hospitals *P. aeruginosa* is most commonly recovered from moist environments [1—3]. Faucets and tap water have been frequently identified as potential sources of infection and outbreaks in ICUs [4—6]. Additionally, sink drains are frequently colonized with potentially pathogenic micro-organisms, especially non-fermenting Gram-negative bacteria. It is unclear whether sinks may contribute to transmission of these bacteria to patients, or even serve as a source of outbreaks [7—10].

We have previously described a prolonged outbreak with a multidrug-resistant strain of *Pseudomonas aeruginosa* (MDR-PA) in the ICU of the Leiden University Medical Centre [11]. From February 2009 to January 2012, 44 patients on our ICU were found to be MDR-PA positive. MDR-PA isolates of the 44 patients showed two distinct, amplified fragment length polymorphism (AFLP) patterns, with homology within each of the AFLP clusters of >93%. The metallo-β-lactamase VIM-1 gene was detected in 20 out of 21 tested isolates. Testing of potential sources revealed that most sink drains were intermittently positive for the outbreak strain on all ICU subunits. Moreover, MDR-PA was also cultured from two out of 16 faucets in the ICU.

In November 2011, a policy to replace all contaminated faucets and all faucet aerators on all ICU subunits four times yearly resulted in no reduction in the prevalence of MDR-PA [11]. Thus, it was unlikely that faucets had been the source of the prolonged outbreak. To decrease the risk of infection with MDR-PA we subsequently targeted the sinks to reduce the potential reservoirs of MDR-PA in our ICU. Repeated chlorination of sink drains was ineffective [11]. Therefore, from April 2013 onwards, a two-armed intervention trial was performed by installing special siphons containing disinfection devices in one of the two physically separated subunits of the ICU, and the rate of colonization of both the sinks and the patients admitted in the ICU was subsequently determined. In February 2016, the disinfection devices were also installed on the other ICU subunit. Here we describe the effect of the placement of the sink drain disinfection device on colonization with MDR-PA of the sink drains in the ICU, and on the incidence of MDR-PA in ICU patients.

Methods

This prospective observational study was registered in the Netherlands Trial Register under number NTR 4662. Ethical approval was granted by the Medical Ethical Committee of the Leiden University Medical Centre (CME-P18-114). The need for informed consent was waived in view of the observational character of the study. It was conducted at the Leiden University Medical Centre, a tertiary care and teaching hospital in The Netherlands with 30 ICU beds for adult patients with mixed surgical and medical admissions. The ICU is physically divided into two parts, separated by a corridor, both consisting of two subunits: ICU A (subunits 1 and 2) and ICU B (subunits 3 and 4). Patients of different referring specialties are allocated in a random fashion to any subunit, depending on availability of free beds. Treatment protocols, strict hygienic measures, as well as medical staffing are identical in the ICU. Nursing staff are allocated to one of the subunits.

Patients with an expected duration of mechanical ventilation >48 h are treated with selective decontamination of the digestive tract [12]. Antibiotic stewardship and infection prevention form an integral part of medical policy. The Leiden University Medical Centre adheres to the five moments of hand hygiene protocol with active education and feedback to nurses and physicians [13]. Standard contact isolation, including use of single-patient rooms, disposable gowns, and the use of gloves when touching a patient, was used for all patients colonized with MDR-PA.

Intervention

In April 2013 a two-armed intervention trial was initiated by installation of disinfecting devices for sink drains (MoveoSiphon ST24; MoveoMed, Radebeul, Germany) (Figure 1) at all sinks in ICU A. In ICU B new conventional polyvinyl chloride (PVC) plastic siphons were placed (control).

MoveoSiphons are metal devices that aim to decontaminate waste water in the siphon basin by repeated heating to a temperature of at least 85°C every time water flows into the siphon. In addition to heating, it is claimed that the MoveoSiphon cleans the inside of the siphon by electromechanical vibration [14,15] (https://medtradex.com/assets/Uploads/Brochure-Moveomed-MoveoSiphon-ST24-EN.pdf). In December 2013 the MoveoSiphon installation was modified by replacing the plastic connection between the washing basin and the siphon by a metal one to improve heating of the proximal part of the installation. In February 2016, MoveoSiphon ST24 was also placed at all sinks in the control units of ICU B.

From December 1st, 2010, cultures from samples collected during routine patient care were analysed for presence of MDR-PA. From August 2011 samples from all 26 sinks at ICU A and all 21 sinks on ICU B were taken using swabs from the sink drains which were cultured for 15—18 h at 35°C in a selective broth containing vancomycin 8 mg/mL and cefotaxime 0.25 mg/L. The broth was subcultured on MacConkey agar with tobramycin (8 mg/L) (bioMérieux, Marcy l'Etoile, France). Bacterial identification was obtained by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (Bruker Daltonics, Bremen, Germany). Susceptibility patterns were acquired with Vitek 2 (bioMérieux) and by using the interpretative criteria of the European Committee on Antimicrobial Susceptibility Testing (EUCAST). For this study MDR-PA was defined as *P. aeruginosa* resistant to meropenem, tobramycin, and ceftazidime. Cultures from patients (e.g. sputum, blood, urine, ascites) were taken when clinically indicated by discretion of the treating physician. In addition, rectal cultures were done every week routinely in all patients.

Statistical analysis

Primary endpoint was the proportion of sinks colonized with MDR-PA. Secondary endpoints were the proportion of patients colonized with MDR-PA and the presence of MDR-PA in samples taken from ICU patients per 1000 admission-days. In this last

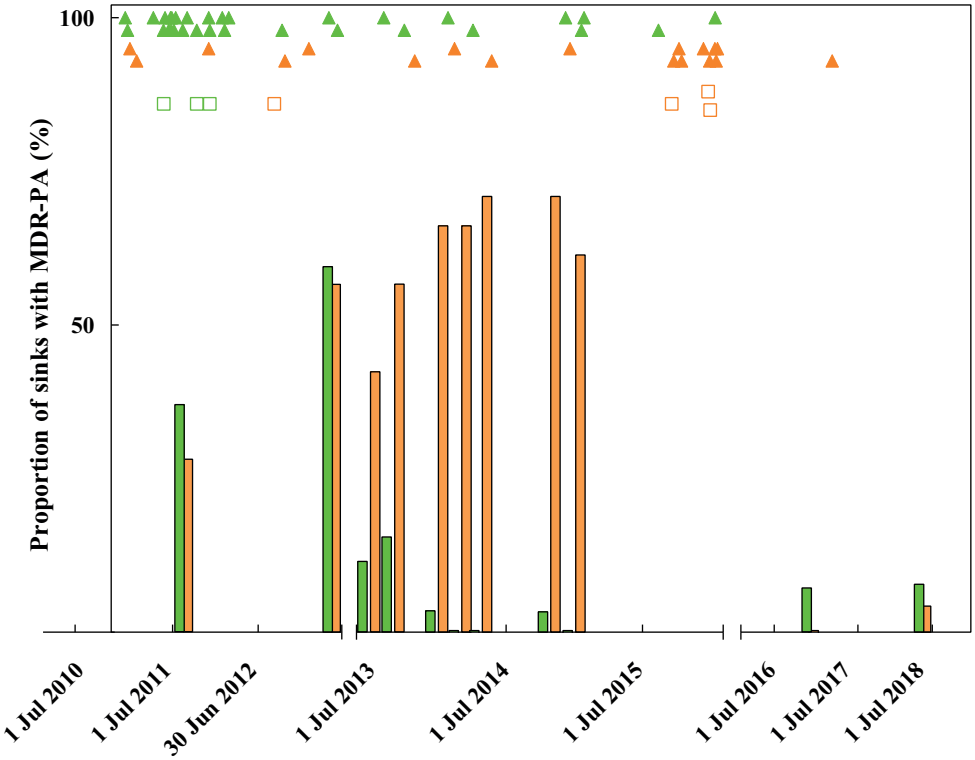

Figure 1. Proportion (%) of sink drains colonized with multidrug-resistant *Pseudomonas aeruginosa* (MDR-PA) (bars). Triangles represent unique intensive care unit (ICU) patients colonized at any body site with MDR-PA. Squares represent unique patients with at least one positive blood culture with MDR-PA. Green symbols and bars represent ICU A; orange symbols and bars represent ICU B. Disinfecting siphons were installed on April 30th, 2013 in ICU A and on February 4th, 2016 on ICU B.

analysis, a patient could have more than one positive culture from different sites (e.g. blood, tracheal aspirate, throat), but per site only one positive culture was included. Pearson χ^2-tests were performed to compare proportions between groups.

Results

ICU A was in use from 2008. ICU B was in use from December 2010. The effects of installation-disinfecting siphons on MDR-PA colonization are shown in Figure 1 and Table I. In the pre-intervention period, from December 1st, 2010 until April 30th, 2013, MDR-PA was cultured from 21 out of 41 (51.2%) tested sinks in ICU A and from 16 out of 35 (45.7%) tested sinks in ICU B ($P = 0.6$). During that same period, MDR-PA was cultured from 48 sample sites in 22 patients in ICU A, mostly from tracheal aspirate or bronchoalveolar lavage fluid ($n = 18$), rectum/perineum ($n = 10$), throat ($n = 4$), blood ($n = 3$), and other sites ($n = 13$). In ICU B, MDR-PA was cultured from 18 sample sites in five patients (tracheal aspirate/BAL ($n = 5$), rectum ($n = 5$), blood ($n = 1$), throat ($n = 1$), other ($n = 6$)). Colonization with MDR-PA was present in 8.3 and 2.7 per 1000 admitted patients ($P = 0.02$) in ICU A and ICU B, respectively. The number of different cultures with MDR-PA was 4.8 and 2.5 per 1000 patient-days in ICU A and ICU B respectively (not significant).

In April 2013, 26 sinks in ICU A (18 located in patient-rooms, eight in utility-rooms) were equipped with the MoveoSiphon installation, and 21 sinks in the control wards (16 in patient rooms, five in utility rooms) were equipped with new conventional PVC syphons (control). From April 30th, 2013 until February 4th, 2016, all sinks in the ICU were cultured on seven occasions. In ICU A, colonization with MDR-PA decreased to 5.1% ($P < 0.001$), whereas it remained high (61.9%) in ICU B. In February 2016, the disinfecting siphon was also installed in ICU B. After this second intervention, until July 1st, 2018, colonization of sinks was 8.0% and 2.4% in ICU A and ICU B, respectively, both significantly lower than in the pre-intervention period ($P < 0.001$). In ICU A the number of MDR-PA-positive cultures from patients significantly decreased from 4.8 per 1000 patient-days in the pre-intervention period to 2.1 per 1000 days in the first intervention period ($P < 0.001$) and 0% in the second intervention period ($P < 0.001$). In ICU B, the number of MDR-PA cultured from patients decreased from 2.5 per 1000 days to 0.2 per 1000 days after installation of the disinfecting siphons ($P < 0.001$).

Discussion

Our findings show that MDR-PA was effectively eradicated from sink drains by a device that applies heating and vibration and that this disinfection resulted in a marked decrease in colonization of patients with this MDR-PA.

From previous studies, it was well known that sink drains in hospital wards harbour pathogenic bacteria that may be resistant to many antibiotics: non-fermenting Gram-negative bacteria [7,9,10,12]. However, these bacteria don't necessarily form a source of transmission to patients. Alternatively, their presence in sink drains may reflect the fact that bacteria colonizing patients and their environment eventually will enter

Table I
Culture of *Pseudomonas aeruginosa* resistant to both ceftazidime, tobramycin, and meropenem in samples from patients and sinks in the ICU

	Pre-intervention		Intervention 1		Intervention 2	
	ICU A	ICU B	ICU A	ICU B	ICU A	ICU B
Intervention	—	—	MoveoSiphon	—	MoveoSiphon	MoveoSiphon
No. of admitted patients	2646	1865	3061	2557	2170	1855
No. of patient-days	9931	7060	10,864	8284	7458	6057
Patients with MDR-PA	22	5	10	12	0	1
Patients with MDR-PA per 1000 admitted patients	8.3	2.7	3.3[a]	4.7	0[b]	0.5
MDR-PA in patient samples						
Total	48	18	23	32	0	1
Blood	3	1		3		
Sputum/bronchoalveolar lavage	18	5	8	5		
Ascites			1	1		
Rectum	10	5	7	9		1
Throat	4	1	4	5		
Other	13	6	3	9		
MDR-PA in patient samples (per 1000 days)	4.8	2.5	2.1[b]	3.9	0[a]	0.2[b]
Sinks with MDR-PA per sinks tested (%)	21/41 (51.2)	16/35 (45.7)	9/178 (5.1)[b]	78/126 (61.9)	4/50 (8.0)[b]	1/42 (2.4)[b]

MDR-PA, multidrug-resistant *Pseudomonas aeruginosa*; ICU, intensive care unit.
Pre-intervention period was December 1st, 2010 until April 30th, 2013. Intervention period 1 was from May 1st, 2013 after placement of a disinfecting device (MoveoSiphon ST24) on all sink drains in ICU A until February 4th, 2016. Intervention period 2 was from February 6th, 2016 after additional placement of a disinfecting device on all sink drains in ICU B until July 1st, 2018. Samples from patients were taken as clinically indicated or as part of routine cultures for selective decontamination of the digestive tract. Per patient and per sample site, only one positive culture was counted. BAL is bronchoalveolar lavage fluid.
[a] $P = 0.01$.
[b] $P < 0.001$ by χ^2-test for difference with pre-intervention period.

sinks, e.g. via water that was used for washing patients or cleaning beds and their surroundings. If so, colonization of sink drains would be merely a reflection, not a source, of the presence of resistant bacteria in the ICU. Although some studies have shown that disinfection or removal of sinks was associated with a decrease in colonization with Gram-negative bacteria of patients, these studies used historical controls [8,14,16]. As these interventions often are instituted in times of high prevalence of resistant bacteria, 'regression toward the mean' or institution of other infection control measures cannot be excluded as explanations for the reported improvements.

To the best of our knowledge, our study is the first using a concurrent control group. Thus, it is highly unlikely that the decrease in prevalence of MDR-PA is caused by other measures that all would be identical in the intervention and control groups. Not only colonization of sinks, but also colonization of ICU patients was prevented by this intervention. These results are important and convincing evidence that colonization of sinks is a source of infection of ICU patients that may contribute to prolonged outbreaks. In our study this is shown for MDR *P. aeruginosa*, but it is likely that sink drains may also be a source of infection with other strains of *P. aeruginosa* and other bacteria that thrive in moist and biofilm-rich environments. The mechanism by which bacteria present in sink drains may be transmitted to patients is unclear. It may be hypothesized that the hands of healthcare workers can be colonized by splash water or aerosols formed when tap-water is flowing in the contaminated sinks.

Although installation of MoveoSiphons on sink drains rapidly and markedly decreased colonization with MDR-PA, it was not 100% effective. As can be seen in Figure 1, some sink drains occasionally tested positive for MDR-PA. A possible explanation is that the siphon draining the sink is disinfected temporarily by the applied device, but the draining tubing more distal from the siphon will remain colonized. As the device will heat the siphon only every time water is flushed, disinfection may be ineffective if the sink is not used regularly, e.g. if a bed is not occupied for some time. Therefore, we propose that some water should be flushed in every sink at least once a day, although this recommendation is not supported by evidence.

Since February 2016, after installation of a disinfecting device on sink drains in all ICU beds, MDR-PA almost disappeared with prevalence in patient samples being 0 and 0.2 per 1000 patient-days in ICU A and ICU B respectively. By contrast, in the period that disinfecting devices were installed in ICU A only, the decrease in colonization of patients in this subunit was only from 4.8 to 2.1 per 1000 admission-days while colonization of sinks had almost disappeared. The likely explanation is that some transmission occurred from ICU B to ICU A, through healthcare workers or shared use of equipment. This emphasizes the importance of instituting infection prevention measures on the entire ICU, not on selected beds only.

As an alternative for disinfecting sink drains, others have studied a 'water-free' ICU where all sinks were removed and tap-water was replaced by bottled water and disposable moistened wash gloves were used for washing patients [16]. This policy resulted in a decrease in colonization with any Gram-negative bacteria in ICU patients from 26.3 to 21.6 per 1000 admission-days. These findings are in accordance with our conclusion that sinks are important as a source of

Gram-negative colonization and infection. However, in a water-free environment, also the removal of faucets and tap-water may have contributed to the decrease in colonization of patients [5,6,17].

Some limitations of this study can be addressed. First, we analysed colonization of sinks and ICU patients, rather than infections. We had two reasons not to choose infections as the endpoint of our study. First, as infections are less frequent than colonization, many more patients should be studied to show an effect of the devices. Furthermore, in an unblinded study, it is very important to use unequivocal, 'hard' endpoints. Most infections are difficult to diagnose with certainty. For example, a certain diagnosis of pneumonia requires invasive diagnostic procedures. However, colonization of MDR-PA is easily determined with low risk of bias. Another limitation is the non-randomized nature of this study. However, as both parts of our ICU installed the disinfecting device at different time-points, our design enabled comparison of colonization rates before and after installation of the disinfecting device in the same ICU subunits as well as comparison of colonization rates between similar ICU subunits with and without these devices, making it very unlikely that other measures were responsible for the observed effects.

In conclusion, disinfecting sink drains in an ICU with a device applying heat and vibration almost completely eradicated colonization of sink drains and resulted in a decreased colonization rate of patients with MDR-PA. These devices may be used for control of outbreaks with resistant *P. aeruginosa*. Further research should focus on the effects of these devices on the spread of resistant and non-resistant bacteria in ICU and other hospital wards, and on its cost-effectiveness.

Conflict of interest statement
None declared.

Funding source
This study was funded by the Leiden University Medical Centre. The manufacturer of the studied device did not fund this study in any way and was not involved in the set-up, execution, or publication of this research.

References

[1] Vincent JL, Rello J, Marshall J, Silva E, Anzueto A, Martin CD, et al. International study of the prevalence and outcomes of infection in intensive care units. JAMA 2009;302:2323–9.
[2] Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infect Dis 2006;6:130.
[3] Grundmann H, Kropec A, Hartung D, Berner R, Daschner F. *Pseudomonas aeruginosa* in a neonatal intensive care unit: reservoirs and ecology of the nosocomial pathogen. J Infect Dis 1993;168:943–7.
[4] Cohen R, Babushkin F, Shimoni Z, Cohen S, Litig E, Shapiro M, et al. Water faucets as a source of *Pseudomonas aeruginosa* infection and colonization in neonatal and adult intensive care unit patients. Am J Infect Control 2017;45:206–9.
[5] Garvey MI, Bradley CW, Tracey J, Oppenheim B. Continued transmission of *Pseudomonas aeruginosa* from a wash hand basin tap in a critical care unit. J Hosp Infect 2016;94:8–12.
[6] Venier AG, Leroyer C, Slekovec C, Talon D, Bertrand X, Parer S, et al. Risk factors for *Pseudomonas aeruginosa* acquisition in intensive care units: a prospective multicentre study. J Hosp Infect 2014;88:103–8.
[7] Perryman FA, Flournoy DJ. Prevalence of gentamicin- and amikacin-resistant bacteria in sink drains. J Clin Microbiol 1980;12:79–83.
[8] De Geyter D, Blommaert L, Verbraeken N, Sevenois M, Huyghens L, Martini H, et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrob Resist Infect Control 2017;6:24.
[9] Roux D, Aubier B, Cochard H, Quentin R, van der Mee-Marquet N. Contaminated sinks in intensive care units: an underestimated source of extended-spectrum beta-lactamase-producing Enterobacteriaceae in the patient environment. J Hosp Infect 2013;85:106–11.
[10] Hota S, Hirji Z, Stockton K, Lemieux C, Dedier H, Wolfaardt G, et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. Infect Control Hosp Epidemiol 2009;30:25–33.
[11] Knoester M, de Boer MG, Maarleveld JJ, Claas EC, Bernards AT, de Jonge E, et al. An integrated approach to control a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Clin Microbiol Infect 2014;20:O207–15.
[12] de Jonge E, Schultz MJ, Spanjaard L, Bossuyt PM, Vroom MB, Dankert J, et al. Effects of selective decontamination of digestive tract on mortality and acquisition of resistant bacteria in intensive care: a randomised controlled trial. Lancet 2003;362(9389):1011–6.
[13] Rai H, Knighton S, Zabarsky TF, Donskey CJ. A randomized trial to determine the impact of a 5 moments for patient hand hygiene educational intervention on patient hand hygiene. Am J Infect Control 2017;45:551–3.
[14] Wolf I, Bergervoet PW, Sebens FW, van den Oever HL, Savelkoul PH, van der Zwet WC. The sink as a correctable source of extended-spectrum beta-lactamase contamination for patients in the intensive care unit. J Hosp Infect 2014;87:126–30.
[15] Fusch C, Pogorzelski D, Main C, Meyer CL, El Helou S, Mertz D. Self-disinfecting sink drains reduce the *Pseudomonas aeruginosa* bioburden in a neonatal intensive care unit. Acta Paediatr 2015;104:e344–9.
[16] Hopman J, Tostmann A, Wertheim H, Bos M, Kolwijck E, Akkermans R, et al. Reduced rate of intensive care unit acquired gram-negative bacilli after removal of sinks and introduction of 'water-free' patient care. Antimicrob Resist Infect Control 2017;6:59.
[17] Rogues AM, Boulestreau H, Lasheras A, Boyer A, Gruson D, Merle C, et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit. J Hosp Infect 2007;67:72–8.